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THE EFFECT OF BALL SIZE AND WEIGHT ON BASKETBALL PERFORMANCE

by

BLAINE NICHOLAS SKLERYK

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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OF MASTER OF SCIENCE

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Date.....

This text is dedicated to
my parents Nicholas and Rosalie Skleryk,
for with out their help this study
would not be a reality.

ABSTRACT

Basketballs of different sizes and weights were evaluated to determine their effect on the performance of Canadian intercollegiate basketball players. The effects of hand size and arm strength were also assessed.

Seventy-one female and thirty-five male CIAU basketball players participated in this study. All participants had used the large #7 ball in regular season play, and all females had used the smaller #6 basketball prior to joining their varsity team. The study was conducted in two parts. In part one, a detailed hand size calculation was performed on each subjects dominant hand and maximal wrist and arm strength measures were determined. In part two, the basketball skills of each subject were tested. Three ball types (large ,small, and weighted small balls) were randomly used by subjects performing five basketball skill tests. These tests were selected on the basis of their likeness to the skills of basketball and the statistical significance reported in similar recent studies .

The results showed Canadian varsity women performed equally well with the test balls in all skill items except the dribbling and speed passing tests. Similar to the women, Canadian varsity men performed equally well with all test balls in all but the speed passing skill test. For women, hand size and upper body strength were found to significantly relate to performance in shooting, passing, dribbling and ball control/manipulation however, all correlation values were low dispite

the statistically significant findings. Ball size and weight, and the physical factors of hand size and upper body strength have only a minor influence on the performance of female CIAU basketball players. This influence is not great enough to cause an inferior performance with the traditional large ball. The importance of the finger spread of a players hand while handling a basketball was highlighted. It appears that the wider players fan their fingers (to an optimal limit), the better ball control they will have with any size ball.

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TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
	PURPOSE	2
	SUBPROBLEM	2
	SIGNIFICANCE OF THE PROBLEM	3
	HYPOTHESES	5
	LIMITATIONS	6
	DELIMITATIONS	7
	GLOSSARY OF TERMS	8
II.	REVIEW OF LITERATURE	11
	CURRENT PERSPECTIVE	11
	ATTRIBUTES INFLUENCING PHYSICAL PERFORMANCE	14
	ASSESSING UPPER BODY STRENGTH	17
	HAND SIZE MEASUREMENT	19
	SUMMARY	21
III.	METHODS AND PROCEDURES	22
	SUBJECT SELECTION	22
	MEASUREMENT TECHNIQUE AND PROTOCOL	22
	i) ANTHROPOMETRIC AND STRENGTH MEASURES	22
	a) HAND SIZE	22
	b) ARM STRENGTH	25
	c) WRIST STRENGTH	26
	iia) BASKETBALL SKILL TESTS	27

Chapter Page

BALL TYPES 29

iib) SUBJECTIVE EVALUATION 30

ASSISTANT TRAINING SESSION 30

STATISTICAL ANALYSIS 31

IV. RESULTS AND DISCUSSION 32

SUBJECT GROUP CHARACTERISTICS 32

COMPARISON OF SKILL TEST RESULTS 35

CORRELATION ANALYSIS 36

ANOVA ANALYSIS 43

SUBJECTIVE BALL EVALUATION 47

V. SUMMARY CONCLUSION AND RECOMMENDATIONS 49

SUMMARY 49

CONCLUSIONS 51

RECOMMENDATIONS 54

BIBLIOGRAPHY 56

APPENDIX A : Letters and Questionnaire 61

APPENDIX B : Skill Test Descriptions 65

APPENDIX C : Data Collection Sheet 71

APPENDIX D : Test Basketball Weights 73

LIST OF TABLES

Table	Description	Page
I	Test Basketball Specifications	30
II	Mean and Standard Deviation Scores: Women	33
III	Mean and Standard Deviation Scores: Men	34
IV	Results of Recent Small Basketball Studies	35
V	Female Correlation Matrix	36
VI	Male Correlation Matrix	37
VII	ANOVA Scores: Skill By Ball Type	43
VIII	Results of Subjective Ball Evaluations	47
IX	Weights of The Test Balls (gms)	74

LIST OF FIGURES

Figure	Description	Page
1.	Side Shot Schematic	66
2.	Lay-up Schematic	67
3.	Figure-8 Schematic	68
4.	Dribble Schematic	69
5.	Speed Pass Schematic	70

LIST OF PHOTOGRAPHIC PLATES

Plate	Description	Page
1.	Obtaining a Ball Specific Hand Print	23
2.	Ball Specific Hand Print	24
3.	Arm Strength Assessment	25
4.	Wrist Strength Assessment	26

Chapter I

INTRODUCTION

In many sports various rule and equipment modifications have been made to allow individuals an environment in which they can perform to their greatest potential. These changes are largely due to different hand sizes, varying strengths, skill levels, body heights, etc. Examples of equipment changes made specifically for women can be seen in bowling balls, golf clubs, tennis raquets, the shot, discus and javelin. The intent of these equipment modifications was to enhance the performance of the female athlete. Basketball is one sport where limited equipment modifications have been made for the female participant. In recent years women's basketball has experienced considerable growth in the number of participants and considerable improvement in skill level. This growth has been attributed to the evolution of the sport (Husak, 1984). In the evolutionary process of any sport, many facets of a game are continually revised in order to improve the quality of play.

In an attempt to improve the game of basketball for women in Canada, Critelli (1984) proposed to the Canadian Intercolligate Athletic Union (CIAU) Women's Basketball Coaches Association that a smaller, lighter ball be used in the CIAU women's basketball league. She claimed that the use of a smaller, lighter basketball in the women's game improved ball handling, passing, shooting, dribbling, and air-borne manipulation. Her report stated that "women are playing with a basketball too large for their hands" and that their upper body

strength was not sufficient to handle the regulation basketball. When compared to the men's game, women seem to play in a "slightly awkward" fashion. Critelli suggested that changing to a smaller ball would provide athletic departments with "yet another product to sell" because women's basketball would become more exciting for paying spectators to watch. It would be more like the men's game, with a faster, quicker pace.

PURPOSE

The purpose of this study was to evaluate the effect of basketball size and weight on the skill performance of intercollegiate basketball players.

SUBPROBLEM

The major subproblem was the assessment of the relationship of hand size and upper body strength and basketball performance.

SIGNIFICANCE OF THE PROBLEM

The prime objective of equipment design research in sport is to investigate and eventually optimize performance of athletes using equipment specific to their sport. The results of such studies frequently suggest equipment modifications be made to facilitate an improved performance by the user.

Basketball is one sport where equipment design research has been almost nonexistent. With the exception of a height-adjustable basket and a junior-sized ball for elementary players, the size and weight of the first official basketball has remained the same for college men and women since its initial production in 1941 (Pitts, 1985). It has been suggested that skill performance by women may be limited in those sports which do not have modified equipment designed specifically for their use (Easson, 1978 and Pitts, 1985). The literature attributes differences in height, weight, hand size, and upper body strength between males and females to be responsible for a "handicapped" performance by women (as compared to men) when using equipment originally designed for men (Easson 1978, Husak 1984, Daily and Harris 1984, Critelli 1984, and Pitts 1985). Sport equipment designed for specific use by women has been credited as the major factor responsible for an increased athletic prowess among women participants and has resulted in an increased number of professional women athletes (Pitts 1985).

An attempt to improve the game of women's basketball in Canada has recently been initiated through a report prepared for the Canadian

Intercollegiate Athletic Union (CIAU). Critelli (1984) has proposed that a smaller, lighter basketball be used in the Canadian intercollegiate women's game. A basketball similar to the one proposed by Critelli was adopted for use by the NCAA Women's Division I Basketball League for the 1984-85 season. This change was brought about by a 12-4 vote in favour of the smaller ball during a meeting of the United States Girl's and Women's Basketball Rules Committee (USGWBRC) in April of 1984.

In the United States, the following organizations have moved to a specifically sized smaller basketball for the 1984-85 season:

- The Womens Basketball Coaches Association(WBCA)
- The National Association of Intercollegiate Athletics (NAIA)
- The National Junior College Athletic Association (NJCAA)
- The Amateur Athletic Union (AAU)
- The National Association of Girls and Women Sport (NAGWS)

In following suit, the Ontario Federation of School Sports Association (OFSSA) has also adopted a specific sized smaller basketball for the Girl's Championships, which were held on December 6-8, 1984.

Considerable controversy has surrounded the adoption of the smaller basketball by the United States Girls' and Women's Basketball Rules Committee (USGWBRC). A similar controversy exists in Canada within the Canadian Intercollegiate Athletic Union Women's Basketball Coaches Association. The results of this study will add to the information disclosed by recent studies conducted in the United States.

HYPOTHESES

This study was designed to investigate the following hypotheses:

1. Three basketball types of different weights and circumferences will have a significant effect on basketball skill test performance.

2. Hand size and upper body strength will be significantly related to basketball skill test performance.

LIMITATIONS

The following limitations may have an effect on data collection and subsequent interpretation.

1. Variability among team performances could have been increased because of:
   - the time of a testing session.
   - a change in testing location from team to team.
   - fatigue due to a post-game test session.
   - the players spirits due to win/loss of a basketball game played prior to the test session.
   - the coaches attitude toward his/her team being examined in this study.

2. It was assumed that all subjects performed each of the skill tests to their maximum ability.

3. Although all female participants had some experience with the smaller sized basketball before joining their intercollegiate teams, the acclimation period for both female and male players consisted of only a practice trial with each of the three ball types prior to performing each of the five basketball skill tests.

DELIMITATIONS

This study was delimited to include the following.

1. Seventy one females and thirty five males participating in CIAU basketball competition participated in this study. All participants were healthy individuals who had used the larger ball during regular season play. The sample size was delimited to the number of consenting CIAU basketball teams visiting the University of Alberta during the 1984-1985 pre-season and seasonal play.

2. A test battery of five skill tests were used to examine skill performance in basketball. These tests were similar to those used in previous studies of this nature.

3. The anthropometric and strength measures were delimited to hand size, wrist strength and arm strength.

4. This study was delimited to three basketball types; the current regulation size #7, the proposed smaller size #6, and a weighted size #6 basketball.

GLOSSARY OF TERMS

Torque: The product of the magnitude of an applied force and the perpendicular distance from the point of force application to the axis of rotation.

Arm: Comprised of the muscles of the shoulder, chest, back and the upper limb including the hand.

Arm Strength: Peak torque (ft*lbs) recorded during upper limb extension on a modified Hydra-Gym leg extension dynamometer.

Wrist Strength: Peak torque (ft*lbs) recorded during wrist flexion on a Cybex II Isokinetic dynamometer.

Upper Body Strength: Refers to the measures of wrist strength and arm strength as defined in this glossary.

Hand Area: A surface area contained inside a line tracing the perimiter of a hand print (Photographic plate # 1). This area is a measure of the surface area of a hand as it would contact a size #7 basketball during dribbling.

Hand Length: The shortest distance from the base of the palm to the tip of the second finger of a hand print, along a line parallel to the second finger.

Hand Width: The shortest distance between the tip of the thumb and the tip of the fourth finger of a hand print.

Hand Size: Refers to the measures of hand area, hand length and hand width as defined in this glossary.

Cybex II: An isokinetic device manufactured by Lumex Inc., New York, which is designed to provide accommodating resistance at a set angular velocity and measure the torque about a specific joint in the human body.

Isokinetic: A method of providing a resistive force which varies automatically so as to be continuously equal and opposite to any applied muscular force.

Hydra-gym: A semi-accommodating device manufactured by Hydra-Fitness Industries Inc. which is based on the principles of hydraulics. It provides an increase in resistance as velocity increases.

Omnikinetics: A term defined by Hydra-Fitness Industries Inc. This is a type of training that provides a self-accommodating, variable, isokinetic overload resistance at any joint angle throughout a range of motion and at whatever speed the user is capable of generating.

Coefficient of Restitution (e): The ratio of an objects relative velocity after impact to the relative velocity before impact. A perfectly elastic impact has a coefficient of restitution equal to one, e = 1 (Sandor, 1983). For basketballs, this law is converted to e=(hb/hd)^.5 the ratio of the height of bounce over the height of drop, all taken to the .5 power (Hay, 1973).

Ball Mate: A liquid rubber compound used to occlude leaks and punctures of the inner bladder of air inflated balls. This compound is injected into a ball in liquid form and drys in an even layer inside the bladder of a ball.

Ball specific hand print: A hand print which has the fingers in the same configuration as when dribbling or shooting a size #7 basketball.

Chapter II

REVIEW OF LITERATURE

Throughout the years, countless changes and refinements have been made to the rules of basketball. Because the men's game was felt to be too strenuous for women, certain modifications to the men's rules were adopted for female participants (Mokray, 1962). One of these changes was the introduction of a smaller-sized basketball. This smaller ball emerged shortly after Archer's (1950) observation of boys and girls 8-11 years old experiencing unwelcome difficulty shooting, dribbling and passing the regulation ball. Use of the smaller ball was intended to promote the development of "correct" motor patterns in the various basketball skills for the younger player. It was believed that use of this smaller ball enabled the younger participants to play a faster, more open game of basketball somewhat earlier in their development (Cione, 1962).

CURRENT PERSPECTIVE

The rationale behind the adoption of the smaller ball for women was that the regulation ball was too large and too heavy for women to perform as well as men (Logan, 1978 cited in Pitts, 1985 and Critelli, 1984). In a proposal recently circulated across Canada to the CIAU Women's Basketball Coaches Association, Critelli (1984) claimed there is conclusive evidence that the smaller ball improves performance in women's basketball. Her statement was based on two recent studies (Husak, 1984; and Dailey and Harris, 1984) which focus on the immediate performance of women basketball players using a smaller sized ball.

In his study, Husak attempted to ascertain if significant differences existed between basketball performances of women using the small and regulation size ball. Conducting his study in two parts, he examined this question in both competitive and non-competitive settings. Phase I examined high school-aged girls (mean age of 16 years) performing skill tests from the 1966 AAHPER basketball test battery. Of ten dependent measures calculated, the small ball demonstrated statistically significant superior performance on three tests (timed layups, speed pass, and distance pass). Phase II evaluated the game statistics of 37 basketball games played with the smaller ball. The results generally favoured the smaller ball, with only a minimal effect being observed on shooting. Husak concluded that females suffer from a loss of ball control because their smaller hands contact less surface of the larger ball; and that females require greater arm strength to apply the forces necessary to shoot, dribble and pass the larger basketball.

Dailey and Harris (1984) examined the effect of the smaller basketball comparing an experimental group of players that were younger, shorter, lighter and had smaller hands and less grip strength than the girls in the control group, which used the regulation ball. Their results showed greater support for the smaller ball, observing larger differences than Husak reported. However, they concluded that further research is required to determine what effect palm size has on basketball performance.

Most recently, Pitts (1985) examined the effect of a smaller, lighter basketball on the skill test performance of sixty-nine female high school and college varsity basketball players. As well, she investigated the relationship between selected anthropometric and upper body strength measurements on skill test performance, in which age, height, weight, arm span, hand size, gripstrength and modified push-ups were recorded on all sixty-nine subjects. Skill performance was measured by an eight-item skill test battery from the AAHPER Basketball Skill Test Manual for Girls (1966).

Her results showed that all subjects performed significantly better with the smaller basketball on all eight skill test items ($p<0.01$). The primary anthropometric factors which significantly effected the performance of both basketballs were weight, hand size, arm span, grip strength and push-ups. She concluded that a player who was heavier, had larger hands, longer arms, and greater upper body strength would perform better with both basketballs, but would perform significantly better with the smaller basketball.

The concept of ball proportionality was investigated by McClements, et al. (1982). They compared the performance of girls and women using a standard ball and a smaller basketball. In a second study with younger subjects averaging 11 to 14 years McClements, et al. (1982) used basketballs that were proportional in size and weight to the participant's height. They found no effect due to ball size on the speed dribble, speed pass, and under-the-basket shot tests for either age group. An interpretation of their results suggests that ball size

and weight affects the sending and receiving of balls differently. They found passing a small basketball to be easier, but receiving was facilitated with a larger ball. They concluded that any change in ball size would have offsetting effects since dribbling, passing and rebound-shooting involve both sending and receiving skills.

In a similar vein, Lindeburg and Hewitt (1965) attempted to discover if using a larger than regulation basketball would have an affect on shooting ability and ball handling. Using four different skill tests and a variety of statistical treatments, they concluded that an experimental basketball two ounces heavier and 1 1/4 inches larger in circumference had no appreciable effect on shooting and ball handling but that catching was facilitated with the larger experimental ball. Lindeburg and associates obtained their results using 26 male varsity basketball players as subjects. All studies examining the effects of the smaller basketball on skill performance have used female subjects. No attempt has been made to examine both women and men on the same skill performance tests with different ball sizes and weights.

ATTRIBUTES INFLUENCING PHYSICAL PERFORMANCE

At the rudimentary level, hand size and player strength have been reported as the two key principles responsible for a different performance by women in basketball when compared to men. This has instigated the sudden move to reduce the ball size in women's basketball in North America. In the opinion of Broer (1973), many girls and women lack the strength necessary to perform a one-hand shot from the free throw line. She reported that players with strength

limitations exert forces to near maximal effort just prior to ball release. Kreighbaum and Barthels (1981) further specified that "the more force used, the less accurate the outcome will be" when throwing projectiles.

In a study that examined the kinetic parameters of wheelchair and able body basketball players, Higger (1984) found wheelchair basketball players to generate greater muscle torques in order to propel the basketball towards the rim. Since a wheelchair player's body is positioned lower and most disabled players do not have use of their legs, Higger hypothesized that the propulsive forces generated to deliver the ball to the hoop were derived mainly from the arms and upper body. More specifically he found wheelchair basketball players developed significantly greater shoulder flexion and shoulder extension torques (38% and 45% more) than stand-up basketball players. Wrist flexion and elbow extension torques produced by wheelchair players were also greater than developed by stand-up basketball players but by only 10% and 20% respectively. Higger stated that strength limitations affect shooting and lead to less than optimal performance.

A player with strength limitations may experience difficulty completing accurate and efficient passes and shots on the basket, resulting in an adverse effect on the level of play. This observation is evident among children and high school aged players, but seems to have less of an effect among intercollegiate basketball players (McClements, et al., 1982).

The relationship between selected structural and functional measures of general athletic ability has been investigated in many studies (Rodgers, 1927; Wilmore, 1935; Watson, 1937; Beall, 1939; Cozens, 1940; McCloy, 1942; Jokl, 1973; Alexander, 1976; Boileau and Lohman, 1977; Clarke, Wrenn and Vaccaro, 1979; Vaccaro, Clarke and Wrenn, 1979). In these studies somatotyping, anthropometrics, muscular strength and endurance, and physiological function have been measured to examine the factors that limit or enhance human physical performance. Tests of this type have been used as indicators of general physical condition and provide information which assesses motor ability or predict athletic potential.

Upper body strength has repeatedly been credited in the literature as a major factor affecting athletic performance (Beall, 1939; Wessel and Nelson, 1961; Wilmore, 1974; Clarke et al., 1979; Vacarro et al., 1979). Investigations of strength training responses of males and females have reported males to be significantly stronger then females. Morris (1948) reported the total strength of men to be 40% greater than that of women. In support of Morris's findings, Hettinger (1961) concluded that general muscle strength in women is about two thirds that of men. Wilmore (1974) assessed the strength, body composition and anthropometric dimensions of men and women. Upon completion of a ten week strength training program, a significant increase in strength was observed for both males and females, however the males exceeded the females in all strength measures except in leg strength relative to lean body weight.

Muscular performance has also been examined in basketball players at the elite intercollegiate level. Clarke, et al. (1979) examined muscular strength, muscular endurance, body size and morphological characteristics on thirteen members of the University of Maryland men's varsity basketball team. When they compared their results to a previous study they had conducted on elite female basketball players (Vaccaro, et al., 1979), they found the men to be 60% stronger in the back and leg lift and 30% stronger in grip strength. The two major factors purported to have a direct influence on basketball performance by women are hand size and upper body strength (Critelli, 1984; Husak, 1984; Pitts, 1985). The exact effect these two factors have is still unclear.

METHODS OF ASSESSING UPPER BODY STRENGTH

As a measure of body strength, the hand grip strength test has been an integral part of various earlier strength test batteries (Rogers, 1927; Cozens, 1940; and McCloy, 1942). Grip strength has been reported by Riezebos, 1980 (cited in Pitts, 1985), to be a "representative measure of upper body strength". Other human performance researchers feel that grip strength is too body specific and is only a good measure of forearm strength. Shephard (1969) states:

> "An assessment of strength should include representative testing of arm, leg and back muscles. However, the majority of authors have been content to measure grip strength using some form of hand dynamometer. This provides a rather unsatisfactory evaluation in one person, since muscle strength is commonly localized to a specific region of the body."

Grip strength specificity has been demonstrated through a study

conducted by Bowers (1961), in which he investigated the relationship of hand size and lower arm girths to hand grip strength. Bower found that measurements of hand and finger length and forearm girths were significantly related to hand grip strength but one factor alone could not be singled out as being a good predictor of hand grip strength.

Jensen and Fisher (1979) have stated that the value of measuring isometric strength to predict ability in dynamic motor activities is questionable due to a low relationship found between isometric and isotonic strength measures. Dynamic (isotonic) strength is reported as being nearly three times more significant in predicting a composite index of motor ability than is static (isometric) dynamometrical strength (Larson, 1940). Although static strength measures such as grip strength are easier to measure than dynamic strength, this type of strength measurement has little value to the athlete and coach, because dynamic strength is used most often in athletic performances (Jensen and Fisher, 1979).

McCloy (1934) was one of the first researchers to highlight the importance of arm strength and the need for dynamic strength measurement in athletics. He states:

> "Arm strength is not only strength of the arms them selves but also strength of the pectoral muscles, serratus anterior, the latissimus dorsi and the deltoid. Hence, the strength of arm action is also strength of the muscles that swing the arms as well as the strength of the arms alone".

Montoye and Lamphiear (1977) attribute lack of torso muscle involvement as the major cause of inaccurate arm strength measurments by the

conventional upper body strength tests. In order to obtain the best representative sample of arm strength, this property must be examined in a dynamic environment using a dynamic action that comes as close to the actual sporting activity as possible.

In basketball the muscles of the hands, arms, chest and back are all used to control the ball during play. A dynamic strength measurement which includes these four body areas performing a motor pattern specific to basketball would appear to be a better upper body strength assessment for basketball players than those of grip strength (Burkness, 1939; Heyward and McCreary, 1977; Montoye, 1977; Clarke et al., 1979; Vacarro et al., 1979; Dailey and Harris, 1984; Pitts, 1985), push ups (Pitts, 1985), or chins and dips (Burkness, 1939).

HAND SIZE MEASUREMENT

The influence of body size on physical performance is a matter of common observation. The body size of a gymnast contrasts greatly with that of a basketball player. The athletic abilities of a small gymnast are much different from those of a tall lean forward in basketball. Body size plays a primary role in enhancing or limiting human physical performance in most sporting activities. A factor that has been suggested as a probable influencing factor in basketball performance is hand size. Pioneer research by Beall (1939) has shown hand size to have a significant influence on shooting and ball control in basketball. She states:

"A basketball which is 30 inches in circumference can be securely caught and more easily handled by an individual who has a long hand than by one with a short hand".

The effect of hand size on performance in basketball has been examined by various researchers (Beall, 1939; Burkness, 1939; Dailey and Harris, 1984; Husak, 1984; Pitts, 1985). Methods of measurement have varied between studies. The two prominent measures of hand size reported throughout the literature have been hand length and hand width or breadth, but definitions of these measures were not consistent among studies. To the authors knowledge no attempt has been made to calculate a "ball specific" palm area. Finger spread (Burkness, 1939), hand length (Beall, 1939; Burkness, 1939; Dailey and Harris, 1984; Husak, 1984; Pitts, 1985) and hand breadth (Beall, 1939; Burkness, 1939; Husak, 1984; Pitts, 1985) have been measured. Changes in the length and width of body parts can change the efficiency of physical performance (Boileau and Lohman, 1977). However, Jokl (1973) has reported:

> "... measureable physical attributes do not necessarily exert a comparable influence upon the integrative action of the motor control areas of the central nervous system".

As an example, he compared the different sized hands of two equally outstanding pianists and explained that the coordinative capacities of the human hand are of overwhelmingly greater significance than its size.

The difficulty in measuring body size, composition and structure accurately together with the high degree of inter-relation among these parameters makes it difficult to identify the independent contribution each aspect of the physique makes to physical performance. Hebbelinck and Ross (1974) have concluded there is no single integrated system which provides a comprehensive analysis of size, shape and proportion

in the study of physique and human performance. Further research on the developement of better measures of body size are needed to increase the accuracy with which athletic ability can be predicted. More specifically, an accurate descriptive method of hand size measurement has yet to be described.

SUMMARY

Previous research examining the effects a smaller basketball may have on basketball performance has been outlined. The literature has reported the small ball to both improve and have no effect on performance in basketball. Reasearchers have suspected specific structural and functional factors to have a major influence on basketball performance by women. The current general belief among some investigators is that women are playing with a basketball too large for their hands and upper body strength to properly control. Consequently differences in hand size and varying arm strengths have been labeled as the major cause of a slightly awkward performance by women (when compared to men) using a regulation basketball. Due to the lack of specificity and variety of the measurement methods used to determine hand size and upper body strength, better methods are needed to measure and verify factors which may affect performance in basketball.

With this in mind this study was designed to assess the effect ball size and weight have on basketball performance at the inter-collegiate level. An attempt was also made to determine if hand size and arm strength were limiting factors in the game of women's basketball.

Chapter III

METHODS AND PROCEDURES

SUBJECT SELECTION

Seventy-one female and thirty-five male CIAU basektball players volunteered as subjects for this study. All participants had used the larger (CIAU regulation) ball during their regular season play; and all female participants had played with the smaller ball prior to joining their intercollegiate team. Testing was conducted in the main gym or Universiade Pavillion when each team came to play exhibition or regular season games at the University of Alberta. Written permission from the head coach of each basketball team was received prior to testing.

MEASUREMENT TECHNIQUE AND PROTOCOL

Testing was conducted in two phases:

i) Anthropometric and upper body strength measures

ii) Basketball skill & Subjective evaluation

i) ANTHROPOMETRIC AND UPPER BODY STRENGTH MEASURES

a) Hand Size:

Each subject's dominant hand was measured for length, width, and palm area as shown in photographic plate # 1. These measures were made from a ball specific hand print. Players were required to ink the palm surface of their dominant hand and position that hand on a regulation-sized basketball as they would when dribbling or shooting. As players held their fingers still, an assistant carefully removed their configured hand to the back of that player's data collection

sheet where their palm print was made. This print simulated the fingers and thumb of the player's hand in a configuration that they normally use when shooting or dribbling a regulation-sized basketball. Plate #1 exhibits how a ball specific hand print was obtained. The three hand measurements were calculated using a MOP-3 pen stylus digitizer (Carl Zeiss Inc.). The hand area calculations were derived by the Simpson's Rule. Reliability of the digitization process was determined with a paired t-test. The first thirty data sheets were digitized and then randomly mixed with the remaining undigitized sheets. All data sheets were then processed with the original thirty sheets thus being examined twice.

Plate #1

Obtaining a Ball Specific Hand Print

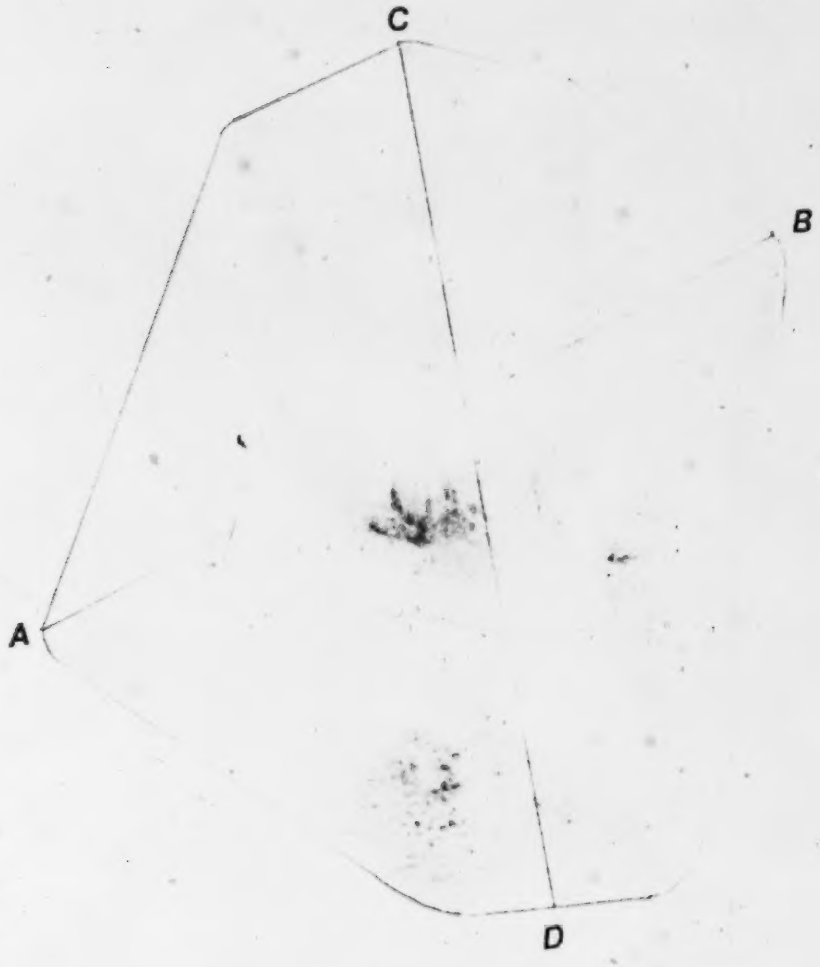

Plate #2

Ball Specific Hand Print

Hand Area: area inside line tracing perimeter of hand
Hand Length: length of line C-D
Hand Width: length of line A-B

b) Arm Strength:

The primary action observed in most basketball skills is flexion of the shoulder, extension of the elbow, and flexion of the wrist.

With this in mind, general arm extension and wrist flexion were measured. Each subject performed a maximal effort arm extension on a modified Hydra-Gym, omnikinetic dynamometer. Participants were asked to position their hands on the T-bar leaver (Plate #3) as if they were about to throw a chest pass in basketball. They were subsequently asked to extend their arms as forcefully and as quickly as possible to full extension. This action of arm extension was intended to simulate a chest pass in basketball. The maximum torque a player could exert during the action of arm extension was determined by performing this action. The best of three peak-torque readings was recorded as maximal arm strength. Reliability of this device was assessed with a series of calibration tests and linear regression analysis.

Plate #3

Arm Strength Assessment

c) Wrist Strength:

Subjects performed maximal effort wrist flexion with their shooting hand on a Cybex II, isokinetic dynamometer set at a speed of 60 degrees per second (Plate #4). The best of three peak-torque readings were recorded as the player's maximum wrist strength. These values were determined from strip chart records of the wrist torques. The action of wrist flexion was examined because it simulated the action of the wrist used in dribbling and shooting a basketball. Moffroid et al. (1969), concluded that peak torque was

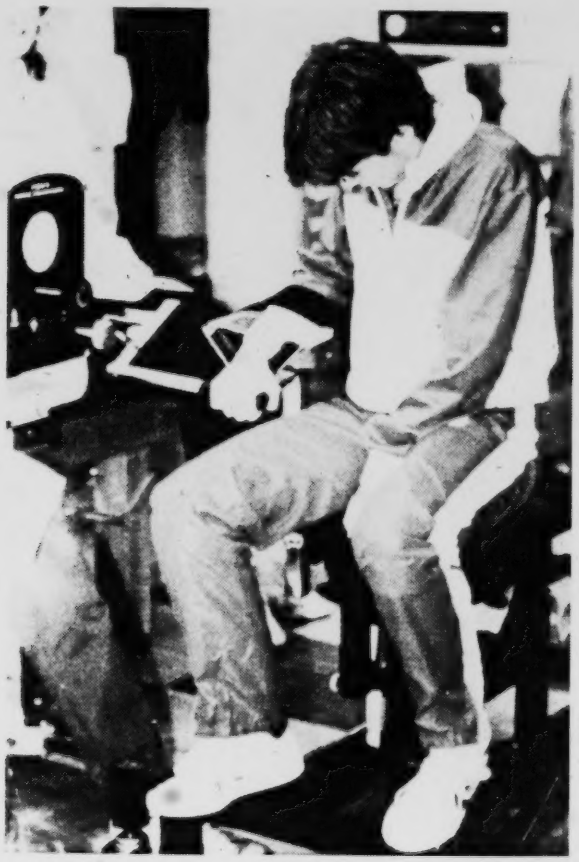

Plate #4

Wrist Strength Assessment

reliably measured on the cybex II, however gravity correction procedures as described by Winter et al. (1981) were not employed in this study . Both the Cybex II and the modified Hydra-Gym dynamometers were routinely calibrated prior to each test session.

iia) BASKETBALL SKILL TESTS

A battery of five basketball skill tests were employed in this study. These tests were the same (in part) as those used by Husak, (1984), and Dailey and Harris, (1984). Test selection was made on the basis of general basketball skill representation, intraclass correlation coefficients (Hopkins, 1979) and statistical significance observed for small and large ball differences reported in the two studies cited above.

Four skill test items from the American Association of Health, Physical Education and Recreation AAHPER Basketball Skills Test Manual for Girls (1966) were used to measure basketball skill performance. These four tests were also used by Husak, (1984) and Dailey & Harris, (1984). A fifth skill test, introduced by Dailey & Harris, (1984) was used to measure ball control. A complete description of administration and scoring procedures for each of the skill test items appear in Appendix B. An overview of the five skill tests and their reliability coefficients (r) are as follows:

1. Lay-up (0.90)~ The purpose of this test was to examine rebounding ability. Each subject was asked to put the ball into the basket as rapidly as possible in 30 sec

2. Side shot (0.86)~ The purpose of this test was to measure a player's shooting ability. Fifteen trials were taken with each ball.

3. Speed pass (0.89)~ This test measured a player's sending and receiving skills. Each participant was instructed to pass a basketball against a wall and catch it as quickly as possible ten consecutive times from a distance of nine feet.

4. Dribble (0.91)~ The purpose of this test was to examine dribbling ability. Each subject was instructed to dribble a basketball around six cones down and back for a distance of 45 feet with either hand.

5. Figure-8 (0.87)~~ The purpose of this test was to examine how well a player could control a basketball. Subjects were asked to move a basketball around their legs in a figure-8 pattern as quickly as possible with out lossing control of the ball.

After all the subjects had been measured for hand size and strength, they were paired with a second subject and instructed to travel from station to station to perform each skill test. A short

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~ From the AAHPER test battery (1966), used by Husak (1984).

~~ From Dailey and Harris, (1984).

practice period was allowed each subject to provide familiarity with the task. Subjects performed each test with each of the three balls. The order of use of the three balls was randomized. The subject pair alternated trials to prevent fatigue from becoming a contributing factor. After each ball type was used by both subjects, the pair moved to the next available testing station.

BALL TYPES

Three basketball types of different combinations of circumference and weight were used in this study. Six balls of each type were clearly labelled with a letter "A", "B" or "C" for identification. Ball type "A" comprised the CIAU regulation (size #7) balls, Spalding Top Flight 100's. The average circumference was 29.5 inches (75 cm) and average weight was 20.5 ounces (580 grams). Ball type "B" consisted of smaller (size #6) basketballs, Spalding Ladies Top Flight 100's with an average circumference of 28.5 inches (73.5 cm) and an average weight of 180 ounces (510 grams). Both ball types "A" and "B" were inflated to the manufacturers recommendation of 9 lbs. pressure. All basketballs labelled "C" were weighted Spalding Ladies Top Flight 100's. The weight of these balls was increased by 2.5 ounces with an injection of a liquid rubber ball sealent to simulate the weight of the regulation size ball. To maintain the same coefficient of restitution as that of ball type "A", all "C" balls were inflated to 12 lbs. pressure. A full discription of each ball type appears in Table I and the weights of all the test balls appear in Appendix D.

TABLE I
Test Basketball Specifications

Ball Types	Inflation Pressure	Mean Circumference	Mean Weight
Ball "A" Large ball/large weight (Regulation size #7 ball)	9 lbs.	29.5" (75 cm)	20.5 oz (580 gms)
Ball "B" Small ball/small weight (Smaller size #6 ball)	9 lbs.	28.5" (73.5 cm)	18.0 oz (510 gms)
Ball "C" Small ball/large weight (Experimental size #7 ball)	12 lbs.	28.5" (73.5 cm)	20.5 oz (580 gms)

iib) SUBJECTIVE EVALUATION

After a group of two subjects had completed all five skill tests, they were asked to subjectively evaluate the test balls. Each subject ranked the three balls in order, from lightest to heaviest and from smallest to largest. They were also asked to choose the ball they preferred. The purpose of this test was to determine if players (of both sexes) could distinguish between balls of different size and weight, and to see what their ball preference was.

ASSISTANT TRAINING SESSION

A pilot test was conducted using players on the University of Alberta women's intercollegiate basketball team to refine test administration and objectify the use of stopwatches and verbal direction to the subjects. Prior to each test session, a group of twelve volunteer undergraduate students were instructed how to administer and score each skill test. Each group of assistants was

briefed on the protocol by the project director for one half hour before the testing began. The project director further organized the assistants in the gymnasium and made sure the tests were administered and scored correctly and consistently.

STATISTICAL ANALYSIS

Data analyses were conducted in two parts to separately answer each hypothesis. Male and female performance data were examined separately in each part. Pearson product moment correlation analyses (BMDP:8D) were conducted to test for significant relationships among five physical measures; (hand area, hand length, hand width, arm strength and wrist strength) and five skill performance tests; (sideshot, lay up, figure-8, dribble and speed pass) with each of the three ball types.

Repeated measures analysis of variance (ANOVA) analyses (BMDP:2V) were conducted on five skill tests. The raw performance data were corrected for the effects of hand area, hand width, hand length, arm strength and wrist strength to determine if significant differences in basketball performance were due specifically to the three ball types. Subsequent Duncan's New Multiple Range (DNMR) post-hoc comparisons were conducted on significant observations from the ANOVA analyses.

Chapter IV

RESULTS AND DISCUSSION

The effect of ball size and weight on basketball performance was investigated in hypothesis one. The relationship of hand size and arm strength with basketball performance was examined in hypothesis two. The results are presented separately for females and males in the following sections:

- Subject Group Characteristics
- Comparison of Skill Test Results
- Correlation Analysis
- ANOVA Analysis
- Subjective Ball Evaluation

SUBJECT GROUP CHARACTERISTICS

The means, standard deviations and extreme values for twenty variables appear in Tables II and III for females and males respectively. It is difficult to draw comparisons between the anthropometric and upper body strength data reported in the present study and similiar data from previous studies, due to the lack of measurement similarity and subject age differences.

TABLE II
MEANS, STANDARD DEVIATIONS, AND LIMIT SCORES FOR
SKILL ,ANTHROPOMETRIC, AND UPPER BODY STRENGTH TESTS
FOR INTERCOLLEGIATE WOMEN

VARIABLE NAME	MEAN	STANDARD DEVIATION	SMALLEST SUBJ.#	SMALLEST VALUE	LARGEST SUBJ.#	LARGEST VALUE
A-SIDE SHOT *	21.0563	3.8799	22	12.0	18	30.0
B-SIDE SHOT	21.4084	3.9008	22	10.0	32	29.0
C-SIDE SHOT	20.8591	3.9611	44	9.0	11	28.0
A-LAY UP **	16.6620	2.2421	34	12.0	67	22.0
B-LAY UP	16.4789	2.2352	16	11.0	27	21.0
C-LAY UP	16.6761	2.5001	22	9.0	67	22.0
A-FIGURE-8 ~~	26.1268	2.5463	8	20.0	44	32.0
B-FIGURE-8	26.4225	2.4240	8	22.0	28	32.0
C-FIGURE-8	25.9296	2.3804	15	21.0	44	33.0
A-DRIBBLE ^	8.6140	1.0548	40	6.4	52	10.8
B-DRIBBLE	8.6492	1.1384	35	6.6	46	12.0
C-DRIBBLE	9.0126	1.2756	35	6.4	52	13.8
A-SPEED PASS ^	9.1084	0.6602	67	7.9	3	11.3
B-SPEED PASS	8.7239	0.6118	69	7.4	70	10.4
C-SPEED PASS	9.5013	0.7750	13	8.0	37	11.5
HAND AREA ^^	187.1248	20.8932	68	150.48	58	264.79
HAND LENGTH ~	15.9186	1.8584	68	12.38	58	23.58
HAND WIDTH ~	17.3469	0.7854	28	15.45	8	19.84
ARM STRENGTH "	122.1259	15.5236	32	96.0	19	163.7
WRIST STRENGTH "	11.1761	2.6757	38	4.5	6	17.5

N=71 Females
* total number of points
** number of baskets
~~ number of cycles
" torque (ft*lbs)
^ time (sec.)
^^ (cm^2)
~ (cm)

TABLE III
MEANS, STANDARD DEVIATIONS, AND LIMIT SCORES FOR
SKILL ,ANTHROPOMETRIC, AND UPPER BODY STRENGTH TESTS
FOR INTERCOLLEGIATE MEN

VARIABLE NAME	MEAN	STANDARD DEVIATION	SMALLEST SUBJ.#	SMALLEST VALUE	LARGEST SUBJ.#	LARGEST VALUE
A-SIDE SHOT *	23.9143	3.3814	19	15.0	25	29.0
B-SIDE SHOT	23.1429	3.5739	8	14.0	22	28.0
C-SIDE SHOT	23.7714	3.2996	8	13.0	22	29.0
A-LAY UP **	19.4286	2.5238	33	14.0	5	24.0
B-LAY UP	19.5428	2.8111	24	11.0	5	26.0
C-LAY UP	20.2857	1.9031	25	16.0	14	24.0
A-FIGURE-8 ~~	28.8571	3.7585	23	20.0	5	35.0
B-FIGURE-8	29.1429	3.6553	7	22.0	16	35.0
C-FIGURE-8	28.5428	3.6083	7	20.0	1	36.0
A-DRIBBLE ^	7.7628	0.6822	25	6.7	34	9.5
B-DRIBBLE	7.8000	0.6620	25	6.9	32	9.4
C-DRIBBLE	7.8914	0.6688	1	6.9	32	9.6
A-SPEED PASS ^	7.5828	0.6176	23	6.5	5	9.2
B-SPEED PASS	7.3943	0.6338	33	6.4	5	9.3
C-SPEED PASS	7.8514	0.6214	25	6.7	5	9.1
HAND AREA ^^	236.2440	27.5980	11	187.28	10	323.53
HAND LENGTH ~	18.1094	1.9715	33	14.76	10	24.70
HAND WIDTH ~	19.3214	1.0566	11	17.14	34	21.74
ARM STRENGTH "	190.5480	22.4736	6	117.6	23	234.1
WRIST STRENGTH "	16.6286	3.6824	17	6.5	34	26.5

N=35 Males
* total number of points
** number of baskets
~~ number of cycles
" torque (ft*lbs)
^ time (sec.)
^^ (cm^2)
~ (cm)

COMPARISON OF SKILL TEST RESULTS

Comparisons can be made between the skill test results of this study and the results of similar tests examined in previous studies of this nature. A summary of the average score values of skill tests appears in table IV for the most recent studies conducted using women as subjects.

TABLE IV
AVERAGE SCORE VALUES OF SKILL TESTS
IN FOUR RECENT SMALL BASKTEBALL STUDIES ON WOMEN

	SIDE SHOT		LAY-UP		FIGURE-8		DRIBBLE		SPEED PASS	
STUDY	sml	lrg	sml	lrg	sml	lrg	sml	lrg	sml	lrg
1 N=71	21.4	21.1	16.5	16.7	26.4	26.1	8.64	8.61	9.72	9.11
2 N=69	23.4	23.1	17.6	15.2	not examined		10.3	11.3	9.1	10.0
3 N=335	19.0	18.5	13.2	12.9	not examined		11.68	11.61	9.96	10.38
4 N=754	not examined		9.26	8.9	21.1	20.4	11.6	11.5	11.78	11.96

sml=Small Basketball lrg=Large Basketbal

STUDY 1: SKLERYK (1985) ..... MEAN SUBJECT AGE 20.2 YEARS.
STUDY 2: PITTS (1985) ..... MEAN SUBJECT AGE 18.1 YEARS.
STUDY 3: HUSAK (1984) ..... MEAN SUBJECT AGE 16.0 YEARS.
STUDY 4: DAILEY & HARRIS (1984) ... SUBJECT AGE RANGE 10-17 YEARS.

Due to differences in subject age and sample size, a wide range of resultant scores appear for the various studies. The average age of the subjects studied by Pitts (1985) corresponds best with the age of subjects used in the present study (study 1). Consequently similarities between the skill test results for these two studies were expected. Comparisons could not be made with the male score values obtained in this study due to the lack of available data.

CORRELATION ANALYSIS

In hypothesis two it was stated that significant relationships would be found between five anthropometric and upper body strength measures and skill performance in basketball. Pearson product moment correlations (r) were conducted to investigate this hypothesis. The correlation matricies for 71 female and 35 male CIAU intercollegiate basketball players are shown in Tables V and VI. Significant relationships were found to exist for 14 of 75 correlations calculated for females and 3 of 75 correlations calculated for males. It is recognized that the correlation values reported to be significant are

TABLE V
CORRELATION MATRIX OF
PHYSICAL FACTORS VS BASKETBALL SKILL PERFORMANCE OF WOMEN

BALL TYPE	SKILL TEST	HAND AREA	HAND LENGTH	HAND WIDTH	ARM STRENGTH	WRIST STRENGTH
A	SIDE SHOT	0.0401	0.1589	-0.1099	0.0546	0.2608*
B	SIDE SHOT	-0.0085	0.1251	-0.1406	0.0716	0.0727
C	SIDE SHOT	-0.0638	-0.0047	-0.1258	0.1380	0.2938*
A	LAY UP	0.1659	0.0739	0.2276	0.1344	0.1279
B	LAY UP	0.0691	-0.1046	0.2240	0.1331	0.1678
C	LAY UP	0.0183	-0.0689	0.0973	0.1593	0.1063
A	FIGURE-8	-0.1162	0.0730	-0.3450**	0.2747*	0.1361
B	FIGURE-8	-0.1340	0.0520	-0.3546**	0.0736	-0.0816
C	FIGURE-8	0.0033	0.1561	-0.2038	0.0808	0.0614
A	DRIBBLE	0.2414*	0.1713	0.3301**	0.1362	0.2870*
B	DRIBBLE	0.2508*	0.1959	0.2937*	0.0690	0.1179
C	DRIBBLE	0.3146**	0.2242	0.3586**	0.0024	0.1333
A	SPEED PASS	-0.2438*	-0.1950	-0.1839	-0.2039	-0.1276
B	SPEED PASS	-0.1964	-0.0961	-0.2002	-0.1790	-0.1065
C	SPEED PASS	-0.2506*	-0.1955	-0.1961	-0.1859	-0.1324

* $p<0.05$ @ 70 df
** $p<0.01$ @ 70 df

TABLE VI
CORRELATION MATRIX OF
PHYSICAL FACTORS VS BASKETBALL SKILL PERFORMANCE FOR MEN

BALL TYPE	SKILL TEST	HAND AREA	HAND LENGTH	HAND WIDTH	ARM STRENGTH	WRIST STRENGTH
A	SIDE SHOT	0.1525	0.3131	-0.1079	-0.0668	0.0186
B	SIDE SHOT	-0.0614	0.1091	-0.1961	-0.1856	0.0332
C	SIDE SHOT	0.0527	0.1159	0.0105	0.0823	0.1120
A	LAY UP	0.2918	0.2572	0.1789	0.2571	-0.1659
B	LAY UP	0.1853	0.0150	0.2542	-0.0664	-0.1050
C	LAY UP	0.2691	0.2825	0.1322	0.2125	-0.2026
A	FIGURE-8	-0.0836	0.1301	-0.3149	-0.0472	-0.3046
B	FIGURE-8	-0.1590	0.1090	-0.4484**	-0.1021	-0.2090
C	FIGURE-8	-0.2100	-0.0264	-0.4347**	-0.0588	-0.3883*
A	DRIBBLE	0.1226	0.0886	0.1483	-0.1902	0.0342
B	DRIBBLE	-0.0352	-0.0713	0.0299	-0.3220	-0.1559
C	DRIBBLE	0.1170	0.1030	0.0973	-0.0972	0.0742
A	SPEED PASS	0.0453	0.0219	0.0047	-0.2740	0.1378
B	SPEED PASS	0.0576	-0.0407	-0.0618	-0.2853	0.1481
C	SPEED PASS	0.0142	-0.0080	0.0840	-0.3036	0.1545

* $p<0.05$ @ 34 df
** $p<0.01$ @ 34 df

relatively low. These low correlations may or may not be meaningful and are thus discussed below only in the hope that such discussion may provide direction for future studies.

On reviewing the results for women, a significant relationship was observed between wrist strength and side shot performance for balls "A" and "C" in the side shot skill test. Performance in the lay-up skill test was not found to correlate with any of the five physical measures tested. A significant negative relationship was observed between hand width and performance for balls "A" and "B" in the

figure-8 skill test for women. Performance in the Figure-8 test also significantly correlated with arm strength for only the large ball, ball type "A".

Significant positive relationships were observed between dribbling performance and each of hand area, hand width (for all three ball types) and wrist strength (for ball "A"). Since hand area is directly effected by hand width, this result was not surprising. Lastly, a negative relationship between hand area and speed pass performance was observed for the female subjects with ball types "A" and "C".

For the 35 male subjects, the only skill test on which significant correlations were observed with the five physical measurements was the figure-8. As was observed for women, a significant negative relationship was found between hand width and performance in the figure-8 skill test for ball "B" and ball "C". Wrist strength was also found to negatively correlate with figure-8 performance for ball type "C" only.

DISCUSSION

Significant relationships were found to exist between upper body strength and performance in shooting, dribbling and ball manipulation. The correlation analysis revealed results which both agree and disagree with the findings of previous studies. The significant relationship observed between shooting performance and wrist strength for the two heavy balls, ball types "A" and "C", indicated wrist strength and

shooting performance were related for women players using heavier basketballs. However, wrist strength was not related with the shooting performance of intercollegiate women using the smaller ball. These observations are merely confermations of Newton's Second Law of Motion. Large masses require greater propulsive forces to accelerate them as fast as lighter masses. This result is in opposition to the results of Pitts (1985) which reports significant correlations ($p<0.05$) between grip strength (reported to be a good measure of wrist flexion) and performance in shooting for both the small and large ball for college and high school women. A possible explanation of this result could be that there is a "critical ball weight" at which wrist strength is related to shooting success. Basketballs below this critical weight may not affect shooting performance from the free throw line, however ball weights above the critical value could affect shooting performance.

A significant positive correlation was found between wrist strength and dribbling performance with only the large, heavy ball. Although wrist strength may influence dribbling performance in some way, the magnitude of force neccessary to propel a basketball to the floor is probably not a limiting factor in dribbling performance, given the downward direction of the motion. This result disaggrees with the finding of Pitts (1985) which reports a negative correlation between grip strength and dribbling performance for college and high school women using both the large and small ball.

Palm surface area and hand width (Plate #2), was found to correlate significantly with ball control/manipulation in the figure-8 and dribble skill tests and with sending/ receiving skills in the speed pass test. The finding of a significant negative correlation of hand width with ball control in the figure-8 test for balls "A" and "B" was difficult to interpret. A possible explanation of this result could be that the farther players spread their fingers (as indicated by the hand width measure) the flatter and stiffer the palm surface of the hand becomes. This might result in decreased ball control and thus a lower score when performing the figure-8 skill test.

Hand area and width were significantly related with ball control while dribbling for all three ball types. The wider players spread their fingers, the larger the hand contact base area becomes, enabling players to have better ball control when dribbling a basketball. It is possible that there is a defined range of flexibility in which finger spread does not restrict wrist movement hovever, if the fingers are spread beyond that range of flexibility (which is specific for each player) wrist mobility is reduced. The author hypothesizes that when players spread their fingers beyond their specific finger flexibility range, forearm muscle tension increases to impede free wrist movment which could hinder ball control when dribbling. The result discussed here supports the conclusions of Beall (1939) which found hand size to have a significant influence on shooting and ball control in basketball however, it is important to realize that players with smaller hands may be able to control a basketball as effectively as a large handed player by increasing the flexibility of their fingers.

Significant negative correlations were found for hand area and speed pass performance with the two heavy balls, balls "A" and "C". The larger the hand area, the slower the times were for speed pass performance by women. This result parallels the observation of Pitts (1985). She observed a significant negative relationship between hand size and speed pass performance for both large and small balls. A possible explanation of this result could be that placing the fingers closer together improves the conditions for a fast efficient pass. This finger position could be similar to the style used to "set" a volleyball. Players passing a basketball off the palm of their hands utilize only the propulsive forces of arm extension and wrist flexion. Ball velocity is increased when players additionally propel the ball with a quick flexion of the fingers. Players can optimize the speed of a pass by bringing their fingers together to gain the mechanical advantage neccessary to release the ball forcefully off the pads of the fingers.

The results of the present study are not conclusive however, they generally support the results of previous studies which found specific anthropometric factors to affect the skill performance of women in sport (Watson, 1937; Beall, 1939; Everett and Skills, 1952; Wessel and Nelson, 1961; Haymes, 1962; Jakel, 1973; Wilmore, 1975; Alexander, 1976; Boileau and Lohman, 1977; Clarke et al., 1979; Vacuro et al., 1979;).

Significant correlations for male subjects were all negative and limited to one skill test, the figure-8. This suggests that the five

physical factors of hand area, hand length, hand width, arm strength and wrist strength do not have a major influence on the skill performance of the intercollegiate men examined in this study.

Significant negative correlations for hand width with the figure-8 test for balls "B" and "C" were found for men. This finding points to the need to take equal care in not recommending equipment that is too small as is taken in not recommending equipment that is too large.

The significant negative correlation observed between wrist strength and performance in the figure-8 skill test for ball "C" futher reveals the complexity of the strength/ball size relationship. Adjusting the hand to accommodate balls of varying sizes undoubtedly affects the force production capabilities of the forearm musculature.

ANOVA ANALYSIS

In hypothesis one it was stated that the three different ball types examined in this study would have significantly different effects on performance in basketball. Repeated measures ANOVA's (BMDP:2V) were conducted to investigate this hypothesis. The results revealed significant differences among ball types and skill performance on two skill tests for women and one skill test for men. The F values and tail probabilities are reported for five skill tests with each ball type for women and men in Table VII.

TABLE VII
F VALUES FOR BASKETBALL SKILL PERFORMANCE
WITH BALL TYPES "A", "B" AND "C" BY INTRECOLLEGIATE WOMEN AND MEN

	FEMALES df=70		MALES df=34	
TEST	F	PROBABILITY	F	PROBABILITY
SIDE SHOT	0.68	0.5104	1.25	0.2939
LAY-UP	0.31	0.7349	2.48	0.0916
FIGURE-8	2.27	0.1068	0.98	0.3799
DRIBBLE	14.88	0.0000	1.36	0.2641
SPEED PASS	91.62	0.0000	21.81	0.0000

On examining the results for women, significantly different results were observed among the three ball types for the skills of dribbling (F=14.88, p=0.0000) and speed passing (F=91.62, p=0.0000). The average times recorded to complete the dribbling circuit revealed ball "A" to have the fastest mean time of 8.61 seconds, ball "B" with a

slower mean time of 8.65 seconds and ball "C" to have the slowest mean time of 9.01 seconds. Post-hoc examination revealed ball "C", the weighted small ball, to be significantly slower ($p<0.01$) than balls "A" and "B".

The average times for the female subjects to complete ten chest passes in the speed pass skill test revealed ball "B" to have the fastest mean time of 8.72 seconds, ball "A" with a slower mean time of 9.11 seconds and ball "C" with the slowest mean time of 9.50 seconds. Post-hoc examination showed all three ball types to be significantly different ($p<0.01$).

The only skill test that showed a significant difference among the three ball types for the 35 men examined was the speed pass ($F=21.81$, $p=0.0000$). The average times for the male subjects to complete the speed pass were the same as for women in ball order. Players using ball "B" had the fastest mean time of 7.38 seconds, ball "A" had a slower mean time of 7.59 seconds and ball "C" showed the slowest mean time of 7.62 seconds. Post-hoc analysis revealed ball "B" to be significantly faster ($p<0.05$) than balls "A" and "C".

DISCUSSION

The results of this study disagree with the findings of previous studies by Dailey and Harris (1984) and Pitts (1985). The present study revealed the smaller, lighter ball to significantly improve performance on only the speed pass skill test ($p=0.0000$). In comparison, of the same test items examined by Dailey and Harris

(1984), performance with the smaller ball was significantly improved in the side shot, speed pass and figure-8 skill tests (all $p=0.000$) with no effect on dribbling. Pitts (1985) observed performance in the side shot, lay up, speed pass and dribble skill tests to all significantly improve ($p<0.001$) with use of the smaller basketball.

In contrast to those previous studies, Husak (1984) reported a significant improvement in performance in the speed pass ($p<0.000$) and observed a slight improvement in performance for the timed lay-ups ($p=0.074$) with the smaller ball. He found perfomance in the dribbling skill test was slightly better with the large ball. The results of the present study compare best with the findings of Husak (1984).

Both females and males performed significantly better with ball "B" (the smaller, lighter ball) in the speed pass test. This suggests that ball weight was the primary cause of the slower times recorded using balls "A" and "C" (the heavy balls) in that test. This result is not suprissing as Newton's second law of motion dictates that a lighter ball can be passed off a wall faster than a heavier basketball if both balls are acted upon by equal forces. In contrast to the apparent benefits of the small light ball, dribbling performance by women using ball "A" (the large, heavy ball) was significantly better than perfomance using ball "B" (the small, light ball) in the dribbling skill test. These results indicate that a smaller, lighter basketball contributes slightly to an improved skill test performance by men but has offseting effects on the skill performance of intercollegiate women. These results support the conclusions of McClements et al.

(1982) which reports ball size and weight to have offsetting affects on the sending and receiving skills in basketball.

The skill test performance of male varsity players was not dramatically affected by the size and weight of the basketballs tested in this study. It is hypothesized that the "critical ball weight" specific to intercollegiate men is larger than the weight of the large, heavy ball tested in this study. It is possible that there is a "minimum upper body strength level" specific to player age and sex at which point skill performance in basketball is no longer hindered by a specific ball weight. Canadian intercollegiate basketball players appear to possess the required minimum strength.

SUBJECTIVE BALL EVALUATION

The purpose of this test was to determine if players could distinguish between balls of different size and weight, and to determine what their ball preference was. Each subject ranked the three balls in order, from lightest to heaviest and from smallest to largest. They were also asked to choose the ball they preferred. Percent responses appear in Table VIII for female and male subjects.

Table VIII
SUBJECTIVE EVALUATION OF THE THREE BALL TYPES

	N=71 Females	N=35 Males
Chose ball "A" to be large	95.8%	94.3%
Chose ball "B" to be small	52.1%	74.3%
Chose ball "C" to be small	45.0%	25.7%
Chose ball "B" to be light	87.3%	87.7%
Chose ball "A" to be heavy	28.2%	22.9%
Chose ball "C" to be heavy	69.0%	68.6%
Prefered to use ball "A"	71.8%	80.0%
Prefered to use ball "B"	25.4%	20.0%
Prefered to use ball "C"	2.8%	0.0%

DISCUSSION

The response of both female and male players were similar. A high percentage of the subjects were able to correctly choose ball "A" as the large sized ball and ball "B" as the lighter weight ball. Ball

size was difficult to determine for balls "B" and "C" due to the influencing factor of weight. Similarly balls "A" and "C" were difficult to choose for weight because of the confusing effect of size.

The majority of women and men preferred to use ball "A", the current CIAU regulation ball. Substantially fewer players preferred ball "B", the small light ball; and nearly none of the subjects showed preference for the weighted small ball, ball "C".

In an attitude survey conducted by Husak (1984), 33% of the female high school basketball players questioned preferred the large ball, 48% preferred the smaller ball and 19% of the players were undecided. Pitts (1985) found an even higher percentage of high school and college age players she questioned to have a preference for the small basketball. Husak allowed three days of practice with the small and large balls together whereas Pitts (1985) allowed one week of practice with only the small ball. The differences observed between the results of this study and those of Husak (1984) and Pitts (1985) are thought to stem from the age and strength differences of the subjects questioned in each study and the short accomodation time allowed subjects in this study.

Chapter V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The purpose of this study was to determine if the basketball performance of Canadian intercollegiate female and male basketball players was affected by basketballs of different size and weight. The effects of hand size and arm strength on performance were also assessed. Previous studies on this subject (Husak, 1984; Dailey and Harris, 1984; and Pitts, 1985) suggested that insufficient strength and a smaller hand size resulted in lower scores for female players using a large heavy ball than when using a small light ball in various skill tests.

Of the seventy-one female and thirty-five male CIAU basketball players that participated in this study, all had used the large #7 ball in regular season play; and all females had used the smaller #6 basketball prior to joining their varsity team. The study was conducted in two parts. In part one a hand size calculation was performed on each subject's dominant hand, and maximal wrist and arm strength measures were determined on modified isokinetic strength testing equipment. Basketball skill testing and a subjective evaluation comprised part two of the study. Three ball types (large size/large weight, small size/small weight, and small size/large weight) were randomly used by each subject performing five basketball skill tests. These tests were selected on the basis of their likeness to the skills of basketball and the statistical significance reported in the first

two studies cited in the paragraph above. Unlike previous studies, a third weight modified ball was tested with the large and small balls. This enabled the author to determine whether observed differences in skill performance were the result of smaller ball size, reduced weight, or a combination of these factors.

The results showed Canadian varsity women performed equally well with the three ball types in all skill tests except the "dribble" and "speed pass". Similar to the women, CIAU men performed equally well with all test balls in all but the "speed pass" skill test. Analysis of variance data showed that women could pass the small, light ball faster than the other two balls but dribbling speed was fastest using the large ball. Men were also able to pass the small light ball faster than the other two test balls.

Hand size and upper body strength were found to significantly relate to performance in shooting, passing, dribbling and ball control/manipulation only for women. Correlation coefficients were low and it seems evident that ball size and weight, and the physical factors of hand size and upper body strength have only a minor influence on the performance of female CIAU basketball players. This influence is not great enough to cause an inferior performance with the traditional large ball. The importance of the finger spread of a play- ers hand while handling a basketball was highlighted. It appears there is an optimal finger spread specific to each player which assists in improving ball control. The wider players fan their fingers (up to the optimal limit), the better ball control they will have with any ball size.

CONCLUSIONS

Within the limitations of this study, the obtained results led to the following conclusions:

1. Passing speed was found to increase when CIAU women and men used the small light ball. It was concluded that ball weight reduction enhanced passing performance.

2. Dribbling speed was found to increase when CIAU women used the large heavy ball. It was concluded that ball size reduction detracted from dribbling performance.

3. Since passing and dribbling include both sending and receiving skills, it seems possible that a change in ball size and weight has offsetting effects on basketball performance. An optimal ball size and weight has not been determined for use by intercollegiate players.

4. The weighted small ball was found not to improve performance in any of the five skill tests examined. This ball would not be suitable as an alternative to the larger basketball currently used for CIAU intercollegiate play.

5. Men performed equally well with all test balls in all skill tests except the speed pass. It is possible that there is a "critical ball weight" specific to age and sex at which strength is related to success in basketball.

6. The importance of the finger spread of a players' hand while handling a basketball was highlighted in three ways.

a. Hand area and hand width (as measured in this study) were found to correlate significantly with performance in the dribbling skill test by intercollegiate women. The wider players fan their fingers, the greater their hand contact area becomes. This enables players to command better ball control when manipulating, dribbling or catching a basketball. However, it is possible for players to spread their fingers beyond an optimal limit which is specific for each person. This over spreading of the fingers increases forearm muscle tension which impedes free wrist movement and hinders ball control when dribbling.

b. Hand width was found to negatively correlate with ball control/manipulation in the figure-8 skill test for women. It is possible that the farther players spread their fingers (as indicated by the hand width measure) the flatter and stiffer the palm surface of the hand became. This together with an increased muscle tension of the forearm might result in decreased ball control and thus a lower score when performing the figure-8 skill test.

c. Significant negative correlations were found for hand area and speed pass performance with the two heavy test balls. A possible explanation of this result could be that finger tip radius is reduced by fanning the fingers. Players passing a basketball off the palm of their hands utilize only the propulsive forces of arm extension and

wrist flexion. Ball velocity can be increased when players additionally propel the ball with a quick flexion of the fingers. Players can optimize the speed of a pass by reducing the space between their fingers and thus gain a mechanical advantage by increasing lever length when the ball is released forcefully off the pads of the fingers.

7. Wrist strength appears to have more involvment in the skills of shooting and dribbling than does arm strength. It is probable that the precision players require when shooting free throw shots is introduced by specific actions of the wrist and fingers.

8. Even though women were found to have a lower average wrist strength than the men examined in this study, their shooting performance was not compromised by this result. Performances with all test balls in all skill tests that significantly related to wrist strength were equal for women.

9. The physical factors of hand area, hand length, hand width, arm strength and wrist strength did not relate with performance in the skill tests conducted with intercollegiate men using the basketballs examined in this study. It is possible that there is a "minimum upper body strength level" specific to player age and sex at which point skill performance in basketball is no longer hindered by a specific ball weight. It is hypothesized that the "critical ball weight" specific to intercollegiate men is larger than the weight of the large, heavy ball tested in this study.

10. The weight of the large basketball is probably not a limiting factor on ball control and shooting performance of intercollegiate women.

RECOMMENDATIONS

1. The physical factors of hand size, wrist strength and arm strength have some influence on the performance of Canadian intercollegiate female basketball players. This influence is not severe enough to render performance with the large ball inferior to performance using the smaller basketball. It is recommended that the CIAU women not adopt the smaller, lighter size #6 basketball as their regulation ball. However, the use of the small ball for younger, weaker players is advisable. This recommendation is supported by the results of previous studies (Dailey and Harris, 1984; Husak, 1984; Pitts, 1985) and the evidence in this study that shows ball size/weight and player hand size amd upper body strength not to have a major influence on the skill performance of CIAU basketball players.

2. Hand size measurement is task specific. This type of measurement should be conducted on subjects with their hand configured to the position commonly used in their particular sporting enviornment. This will allow researchers to gain a greater insight on what the hand is doing during a specific sporting activity. The author believes the method of hand size measurement used in this study is a better way to measure the hand size of basketball players. Other human performance researchers are encouraged to seek and develop better methods of measuring the effect of body size on performance in sport.

3. Further research is needed to clarify to what extent "critical ball weights" and "minimum strength levels" facilitate an optimized performance specific to player age and sex.

4. A closer examination of how finger position effects basketball performance is recommended.

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APPENDIX A

Team Recruitment Letters and Response Questionnaire

April 10, 1985

Dear Basketball Coach:

Although there has been considerable opinion expressed regarding the suitability of the "small" ball for intercollegiate female basketball players, to date there has been no concrete evidence either supporting or refuting such a change. We encourage you to involve your athletes in this important study at the University of Alberta which will provide much needed information about the relationship of hand size, strength and ball size and specific information about the relationship of these factors for your individual athletes.

Sincerely,

Debbie Shogan
Head Basketball Coach
University of Alberta Pandas

Don G. Horwood
Head Basketball Coach
University of Alberta Golden Bears

DS/cmh

April 10, 1985

Dear Basketball Coach:

Recently there has been some question regarding the size of basketball the CIAU women should use in intercollegiate play. Sport scientists at the University of Alberta have been asked to examine the effect ball type has on skill performance at the intercollegiate level. Since the effects of arm strength and hand size will also be assessed, we are asking both mens and womens intercollegiate teams to participate in this study.

The research group would like to use your basketball team in the subject pool. The study will consist of five basketball skill tests and some measurements of specific anthropometric data on each player. The entire testing time for your team will last about 45 minutes and will all be submaximal in nature.

The results of this study could provide the information needed for an unequivical CIAU ruling on the size of basketball for women at the intercollegiate level. The success of this study rests on a favorable response from the basketball coaches. We hope that you will see the need for a study of this kind and ask your team to take part. Please fill out the response questionnaire attached.

Sincerely,

E. W. Bedingfield
Associate Professor
Sport Performance Unit
The University of Alberta

EWB/sl
Enclosure

RESPONSE QUESTIONNAIRE

Basketball Team Name: _____ M/F

Head Coach: _____ Phone: _____

Address: _____

_____

_____

Please respond to one of the three sections below; A, B, or C:

A. I will encourage my team to participate in your study. We will be in Edmonton from _____ (Date) to _____ (Date). So as not to conflict with our practices and games while at the University of Alberta, I would prefer a:

1. Morning test session at _____ (Time) on _____ (Date).
2. Afternoon test session at _____ (Time) on _____ (Date).
3. Evening test session at _____ (Time) on _____ (Date).

General comments: _____

_____

_____

B. I need more information about this study, please phone me during my office hours: _____ (Day), _____ (Time).

C. I do not wish my team to participate in your study. My reasons for not participating are: _____

_____

_____

_____

APPENDIX B

Basketball Skill Test Descriptions

BASKETBALL SKILL TESTS

Side Shot

1. A subject shoots a total of 15 shots from a spot just outside the free throw line and circle on the left or right side facing the basket. Five shots are taken in three sets, one set at a time. This is repeated for all three ball types.
2. One practice shot is allowed with each ball type.
3. Two points are scored for every basket made without the basketball touching the backboard. One point is scored for a shot which hits the rim (before hitting the backboard) but does not go in. All missed shots receive a score of zero. The maximum score possible is 30 points.

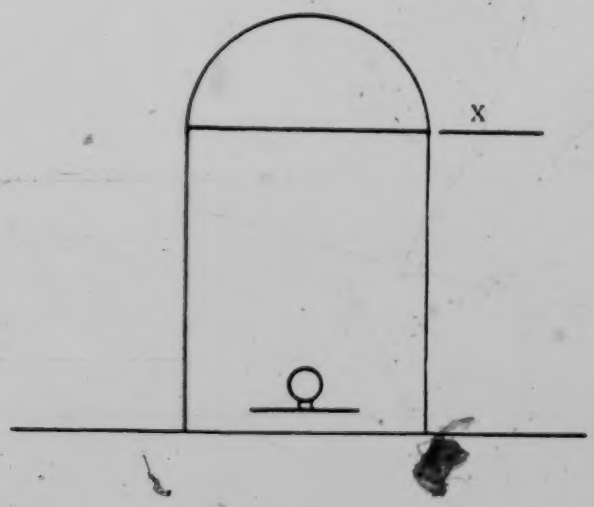

Figure 1

Side Shot Schematic

Lay-Up

1. A subject stands under the basket with a basketball. On the signal "GO", the subject will shoot as many lay-ups as possible within a time period of 30 seconds. This is repeated for all three balls.

2. A short practice trial is allowed with each ball.

3. For each basket made, one point is scored.

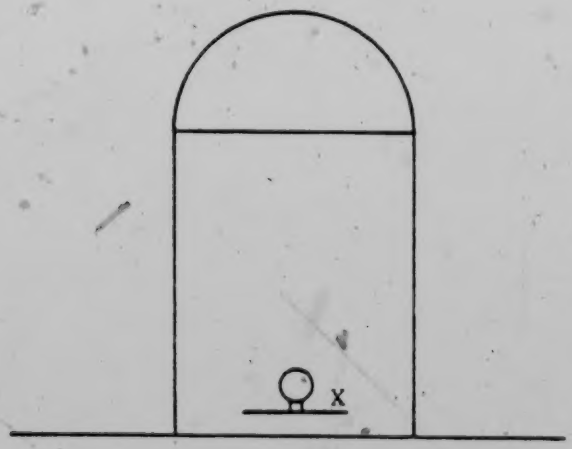

Figure 2

Lay-up Schematic

Figure-8

1. The subject starts with the basketball in a side-stride, bent knee position, with the ball held in front of and between the knees. After being given a starting signal "GO", the subject

will pass the ball around his/her legs in a figure-8 style. One cycle is completed when a figure-8 is completed. This is repeated until 30 seconds has elapsed, for all three ball types.

2. One short practice trial is permitted with each ball type.

3. If the subject drops the ball at any time, he/she must retrieve the ball, return to their original testing location, and continue until 30 seconds has elapsed.

4. The number of cycles completed in 30 seconds is recorded as that subjects score.

Figure 3

Figure-8 Schematic

Dribble

1. A subject stands behind a starting line with a ball facing a line of six cones. On the signal "GO", the subject dribbles the basketball weaving through the cones right to left to the end of

the line of cones and back again. The time is recorded from the moment the subject crosses the start line until the moment the start line is recrossed. This is repeated for all three ball types.

2. One short practice trial is given with each ball type.

3. Legal dribbling must be used (no travelling) and the ball can be bounced with either hand.

4. The time to complete the circuit is recorded as the score.

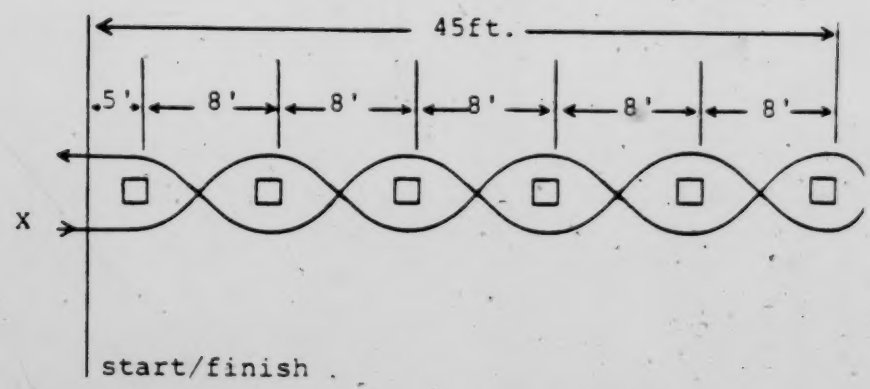

Figure 4

Dribble Schematic

Speed Pass

1. A subject stands behind a line nine feet from a concrete wall. On the signal "GO", the subject will pass the ball against the wall, catching the rebound as fast as possible until 10 consecutive passes have been completed. A stopwatch is started at the

time the basketball strikes the wall for the first time and is stopped the moment the ball strikes the wall for the tenth time.

2. A short practice trial is allowed with each ball.

3. The subject must not step over the nine foot line but reaching is permitted. The ball must be caught and passed, not batted against the wall. If the subject drops the ball at any time, he/she must pick it up, return to the line, and continue until 10 passes have been completed.

4. The proceedure is repeated for all three ball types. Score is recorded in tenths of a second.

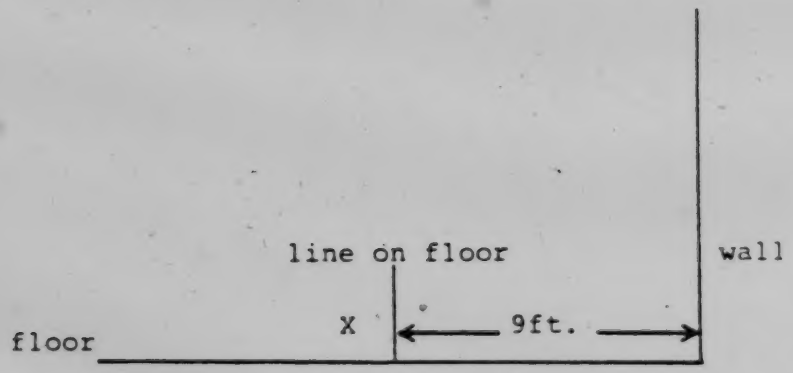

Figure 5

Speed Pass Schematic

APPENDIX C

Data Collection Sheet

SUBJECT #_____ DATE: __/__/__
dd/mm/yy

U of A
SPORT PERFORMANCE UNIT
BASKETBALL STUDY DATA SHEET

NAME:_____ TEAM:_____

AGE:_____ MALE:___ FEMALE:___ YEARS PLAYING BASKETBALL:_____

HEIGHT:_____ WEIGHT:_____ TEAM POSITION:_____

HAND SIZE: L____ W____ A____

ARM STRENGTH: _____ _____ _____ MAXIMUM:_____

WRIST STRENGTH: (MAX) _____

	SIDE SHOT [ ]			LAY-UP [ ]			SPEED PASS [ ]		
	A	C	B~	A	B	C	B	A	C
1	__	__	__						
2	__	__	__	__	__	__	__	__	__
3	__	__	__						
4	__	__	__						
5	__	__	__	FIGURE-8 [ ]			RANK/PREFERENCE		
6	__	__	__	C	B	A			
7	__	__	__	__	__	__	___	___	___
8	__	__	__				small	-->	large
9	__	__	__						
10	__	__	__				___	___	___
							light	-->	heavy
11	__	__	__	DRIBBLE [ ]					
12	__	__	__						
13	__	__	__	B	C	A			
14	__	__	__	__	__	__	BALL PREFERENCE:_____		
15	__	__	__						
TOTALS	__	__	__	COMMENTS:_____					

~ Ball order was randomly assigned.

APPENDIX D

Test Basketball Weights

TABLE IX
Weights of The Test Balls (gms)

BALL "A"
LARGE HEAVY BALL

SPALDING TOP FLIGHT 100

592.26
583.44
584.39
584.81
583.98
615.68

BALL "B"
SMALL LIGHT BALL

LADIES SPALDING TOP FLIGHT 100

518.95
511.57
511.54
522.18
516.33
520.87

BALL "C"
WEIGHTED SMALL BALL

MODIFIED LADIES SPALDING TOP FLIGHT 100

581.37
602.53
581.28
588.80
593.00
579.42